NASA Electrical, Electronic and Electromechanical (EEE) Parts Assurance

An Overview

NASA STEP Level 2

August 17, 2017 Webinar for NASA Safety Center

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Acknowledgment:
This work was sponsored by:
NASA Office of Safety & Mission Assurance

Open Access

Acronyms

- American Association of Independent Advisors (AAIA)
- Automotive Electronics Council (AEC)
- United States Army Aviation and Missile Research Development and Engineering Center (AMRDEC)
- Applied Physics Laboratory (APL)
- Appendix (Appdx)
- Ames Procedural Requirements (APR)
- Ames Research Center
- Commercial Off The Shelf (COTS)
- Canadian Space Agency
- Defense Logistics Agency (DLA)
- Electrical, Electronic, and Electromechanical (EEE)
- Express Logistics Carriers (ELCs)
- Environment Control
- Engineering Practice (EP)
- Electronic Parts Application Reporting & Tracking System (EPARTS)
- EEE Parts Management and Control Plan (EPMCP)
- European Space Agency (ESA)
- Electrostatic Discharge (ESD)
- Electronic Components & Standardization (EZSS)
- Field Programmable Gate Array (FPGA)
- Government-Industry Data Exchange Program (GIDEP)
- Glenn Research Center (GRC)
- Ground Support Equipment (GSE)
- Goddard Space Flight Center (GSFC)
- Human Body Model (HBM)
- NASA Headquarters (HQ)
- IPC is an Association Connecting Electronics Industries. In 1999, IPC changed its name from Institute for Interconnecting and Packaging Electronic Circuits to IPC.
- Institutional Parts Program Requirements (IPPR)
- International Space Station (ISS)
- International Traffic in Arms Regulations (ITAR)
- Japan Aerospace Exploration Agency (JAXA)
- Joint Electron Device Engineering Council (JEDEC)
- NASA Jet Propulsion Laboratory (JPL)
- Johnson Space Center (JSC)
- Kennedy Space Center (KSC)
- Langley Research Center (LaRC)
- Air Force Life Cycle Management Center (LCMC)
- Missile Defense Agency (MDA)
- Military (MIL)
- Military Specifications (MIL Spec)
- Multi-Layer Ceramic Chip Capacitors (MLCC)
- Marshall Space Flight Center (MSFC)
- National Aeronautics and Space Administration (NASA)
- Naval Sea Systems Command (NAVSEA)
- The NASA Electronic Parts Assurance Group (NEPAG)
- The NASA Electronic Parts and Packaging (NEPP) Program
- NASA Policy Directive (NPD)
- A thin layer of p-type semiconductor sandwiched between two n-type semiconductors (NPN)
- NASA Procedural Requirements (NPR)
- NASA Parts Selection List (NPSL)
- National Reconnaissance Office (NRO)
- Office of Management and Budget (OMB)
- Office of Safety and Mission Assurance (OSMA)
- Part Acquisition & Review System (PARS)
- Parts Engineering Technical Standard (PETS)
- Parts, Materials, and Processes Control Board (PMPCB)
- Package on Package (PoP)
- Production Part Approval Process (PPAP)
- Preferred Parts List (PPL)
- Quad Flat-Pack (QFP)
- Qualified Manufacturers List (QML)
- Qualified Product List (QPL)
- Society of Automotive Engineers (SAE)
- Safety and Mission Assurance (SMA)
- Space and Missile Systems Center (SMC)
- System on Chip (SOC)
- Space Station Program (SSP)
- NASA Safety and Mission Assurance Technical Excellence Program (STEP)
- NASA Technology Readiness Levels (TRLs)
- United States Air Force (USAF)

Outline

- Introduction
  - So, What is a EEE Part?
- NASA EEE Parts Assurance Structure
  - Documentation - NASA-STD-8739.10
- NASA Electronic Parts and Packaging (NEPP) Program
  - NASA Electronic Parts Assurance Group (NEPAG)
- Examples of Assurance Challenges
  - EEE Part-level ESD risks
  - Automotive EEE Parts
  - EEE Part problem investigations
    - Reverse-bias of tantalum capacitors
    - Cracking of ceramic chip capacitors
    - Counterfeit trending
- Future Challenges
- Summary and Comments

EEE Part Types Per Table 1 of NASA-STD-8739.10

Part Types	Federal Stock Classes	Part Types	Federal Stock Classes
Capacitors	5910		
Circuit Breakers	5925	Hybrid microcircuits (including dc/dc converters, opto-electronics, RF, and microwave devices)	5962
Connectors	5935	Magnetics, Inductors & Transformers	5950
Crystal & Crystal Oscillators	5955	Monolithic Microcircuits	5962
Diodes	5961	Relays	5945
Fiber Optic Accessories	6070	Resistors	5905
Fiber Optic Cables	6015	Switches	5930
Fiber Optic Conductors	6010	Thermistors	5905
Fiber Optic Devices	6030		
Fiber Optic Interconnects	6060	Transistors	5961
Filters	5915	Wire and Cable	6145
Fuses	5920		

Active Parts

EEE Parts and Space Applications

- **EEE parts are available in "grades"**
  - **Designed and tested for specific environmental characteristics.**
    - **E.g., Operating temperature range, vacuum, radiation exposure,…**
  - **Examples: Aerospace, Military, Automotive, Medical, Extended-Temperature-Commercial, and Commercial**
- **Aerospace Grade is the traditional choice for space usage, but has relatively few available parts and their performance lags behind commercial counterparts (speed, power).**
  - **Designed and tested for radiation and reliability for space usage.**
- **NASA uses a wide range of EEE part grades depending on many factors (technical, programmatic, and risk).**

Compilation of Assorted EEE Parts Photos

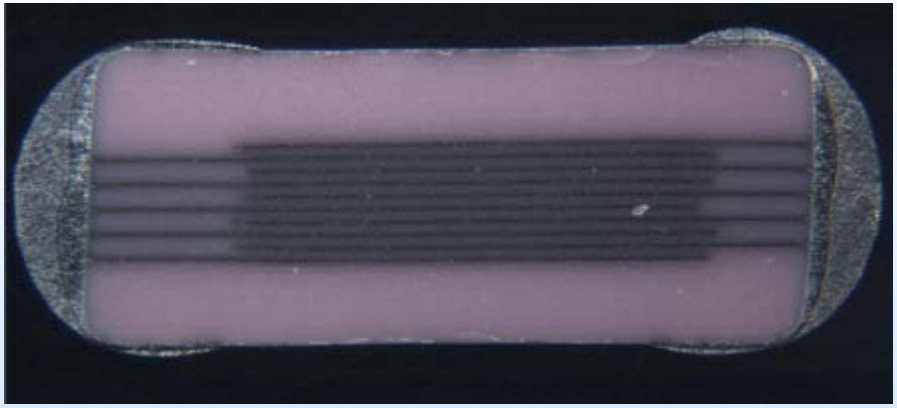
Source: NASA GSFC Code 562 Parts Analysis Laboratory

Compiled by Jay Brusse/ASRC AS&D at NASA GSFC

Some Typical EEE Parts used by NASA

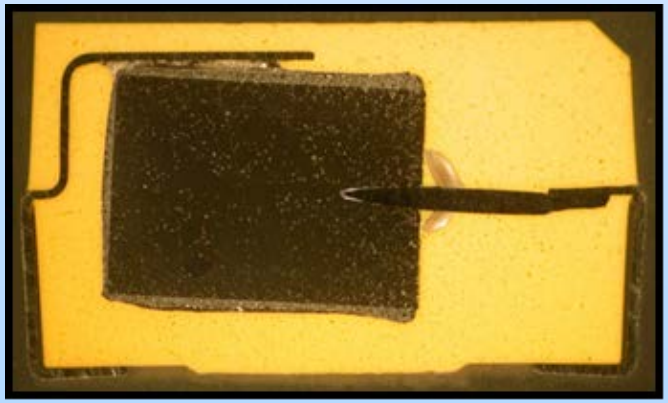
Ceramic Chip Capacitor

Cross Section



Tantalum Chip

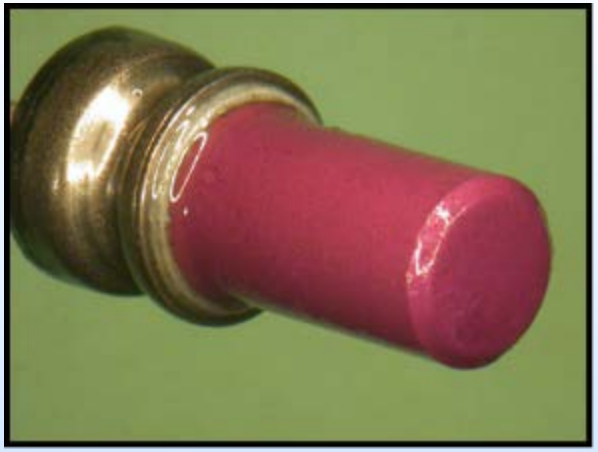
Cross Section



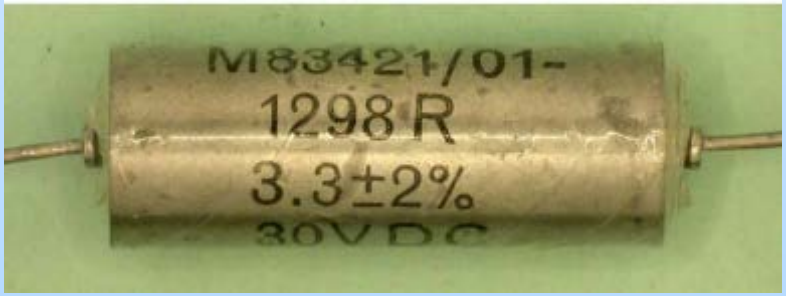
More Capacitors

Wet Slug Tantalum Capacitor

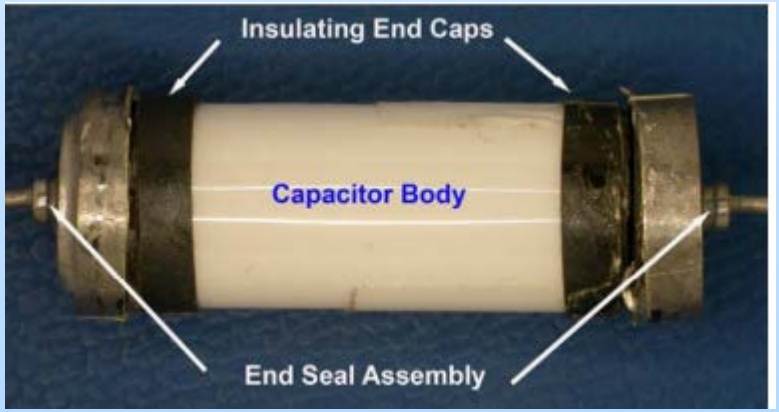
Internal Construction



Metallized Film Capacitor



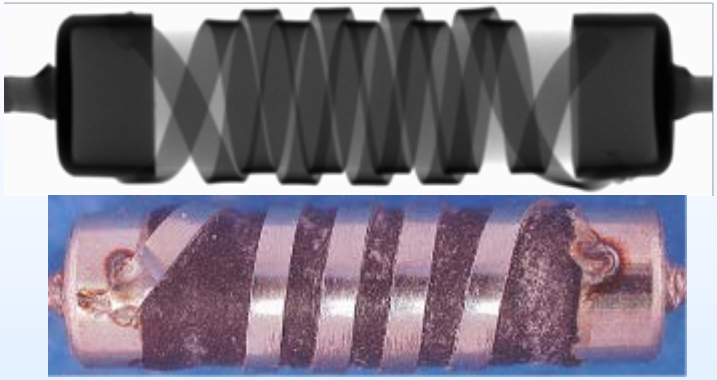
Internal Features



Resistors

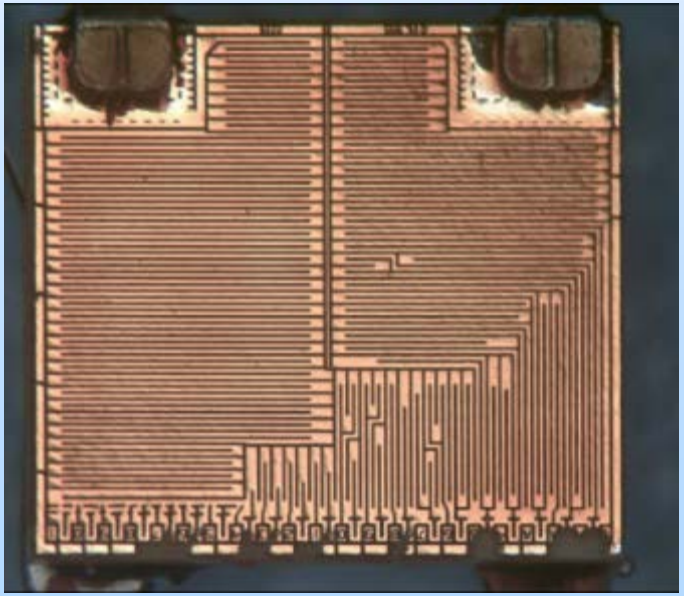
Resistor, Wirewound

Internal Construction



Resistor, Foil

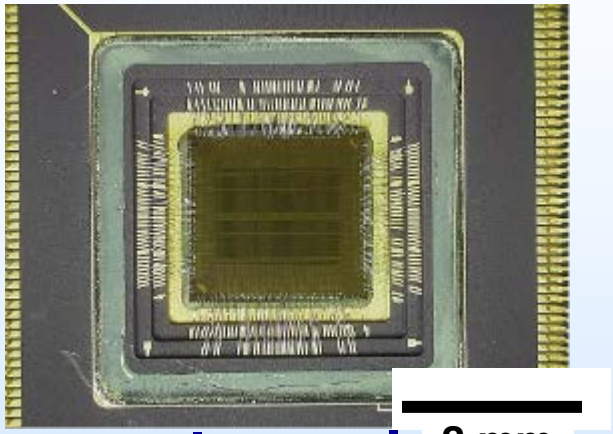
Internal Construction



Microcircuits

Field Programmable Gate Array (FPGA) in a Quad Flat-Pack (QFP)

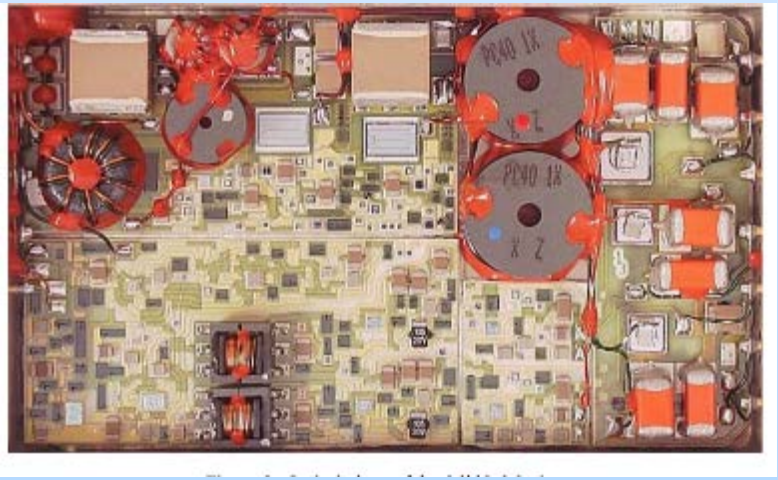
Internal Construction



Hybrid Microcircuit DC/DC Converter

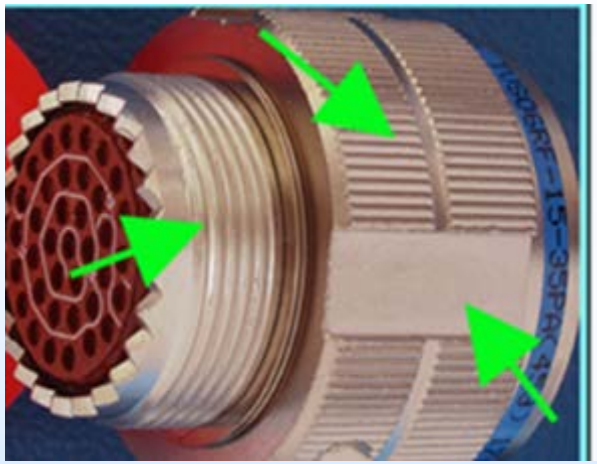
Package 2.2” X 2.7”

Internal Construction

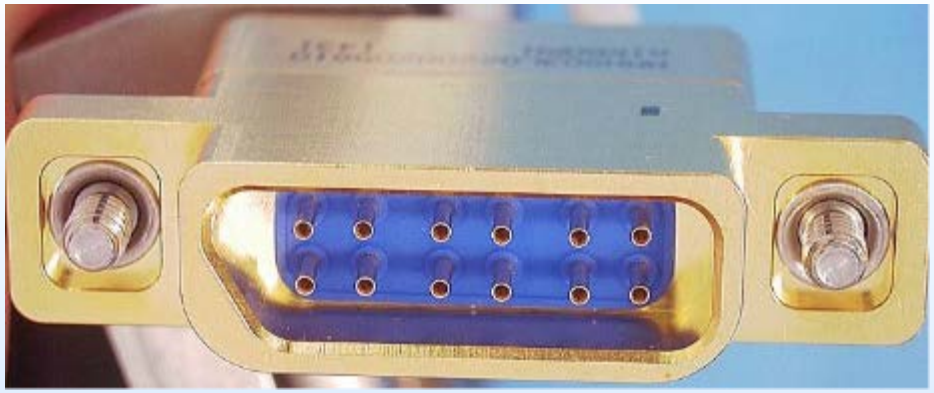


Connectors & Electrical Contacts

Circular Connector

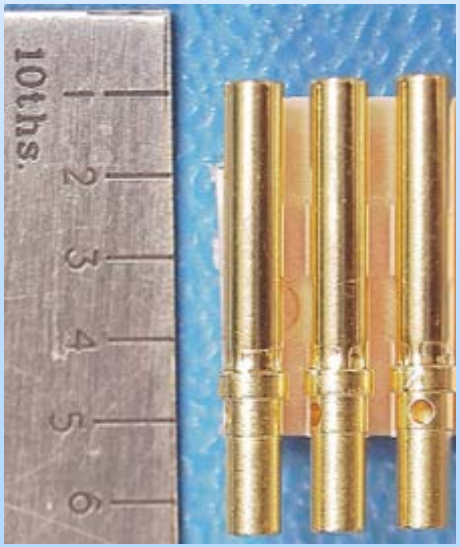


D-Subminiature Connector



Coaxial, Radio Frequency Connector

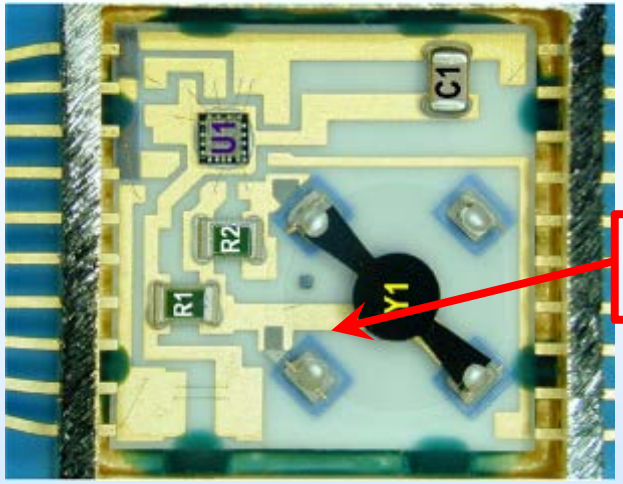
Socket and Pin Contacts



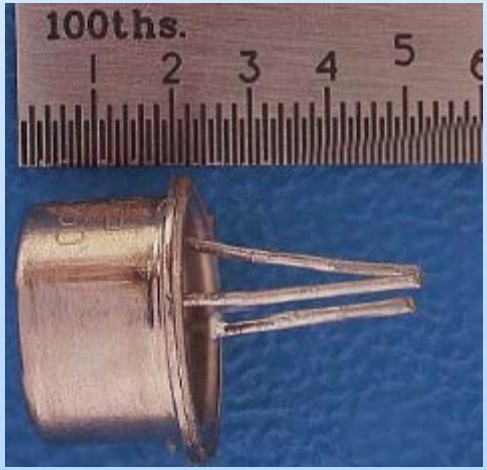
Frequency Control Devices

Crystal Oscillator “Hybrid”

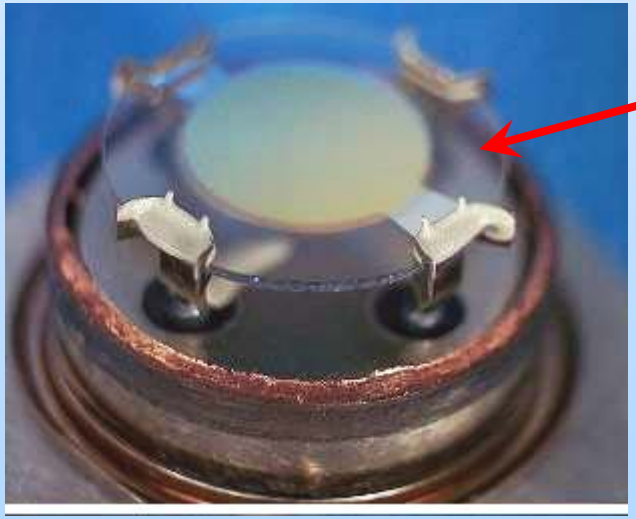
Internal Construction



Crystal



Internal Construction

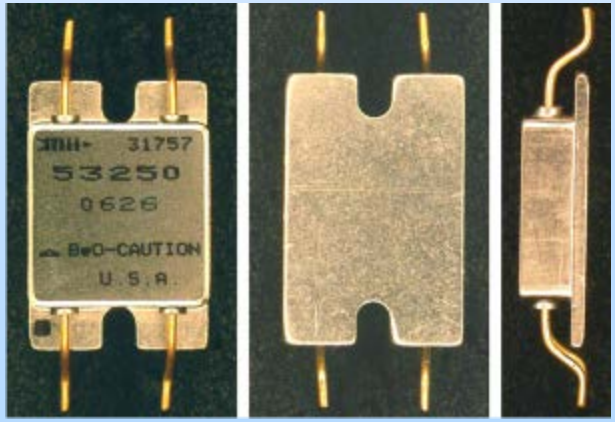


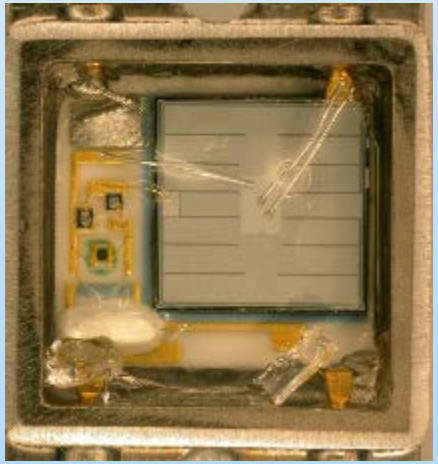
Old Versus New Relay Technologies

Case Removed

Mechanical

Solid-State, Opto-Isolated





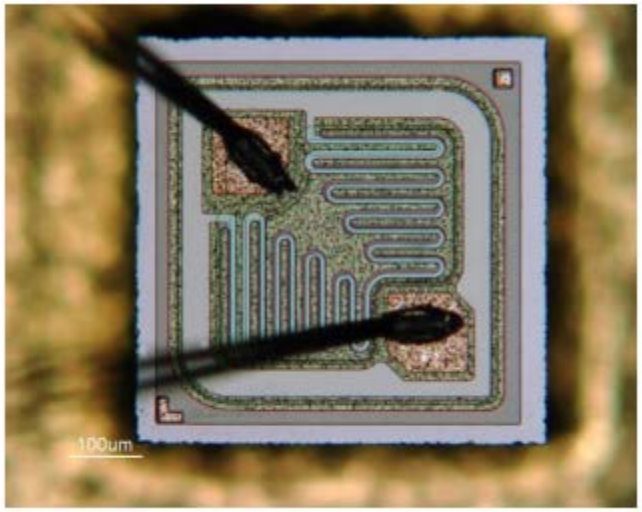
Discrete Semiconductors

MOSFET, P-Channel

Internal Construction

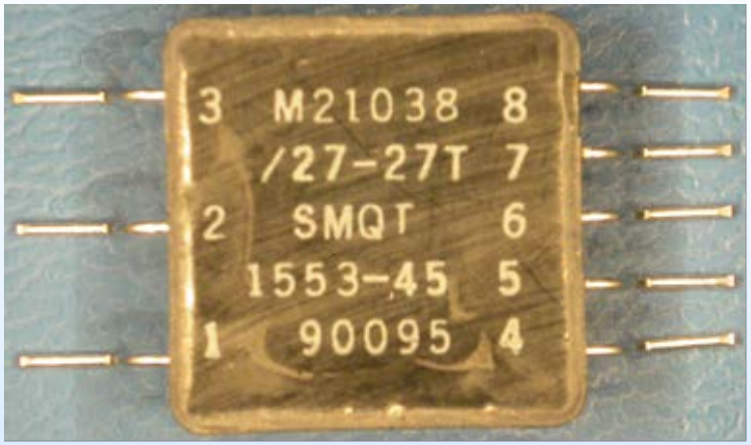
NPN Silicon Switching Transistor

Internal Construction

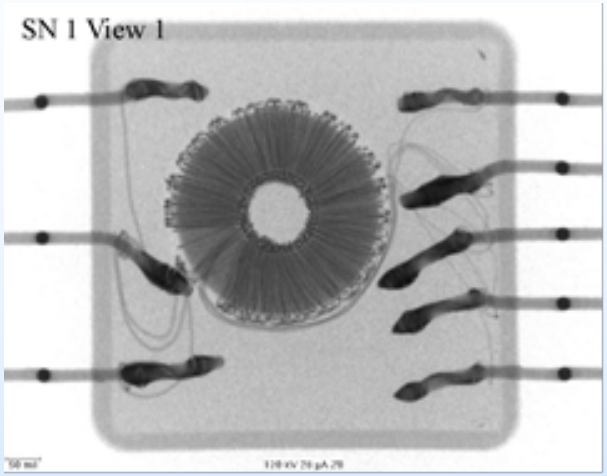


Magnetics

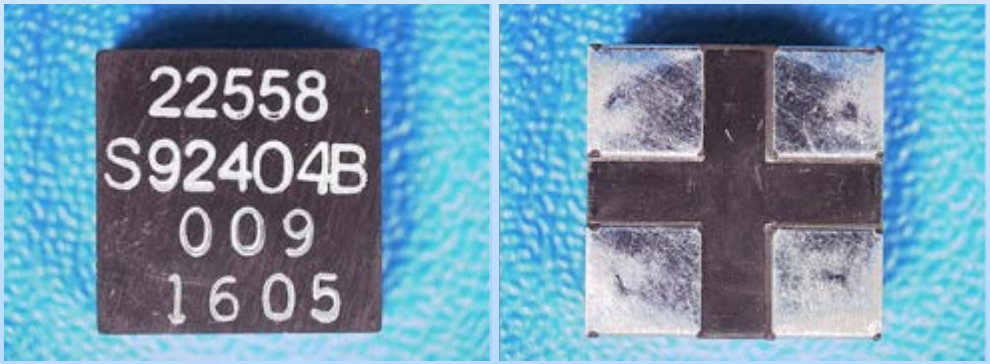
Transformer



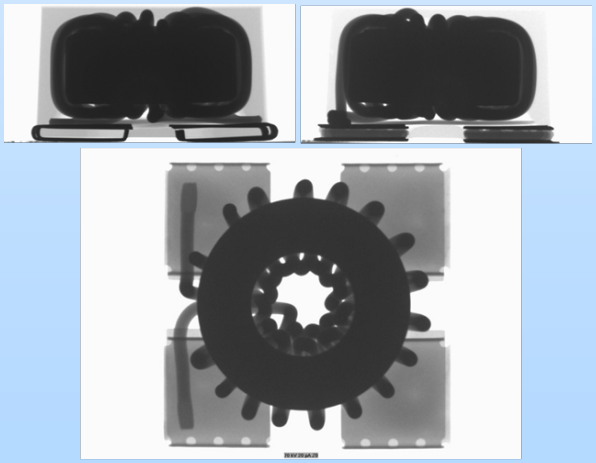
Internal Construction



Power Inductor



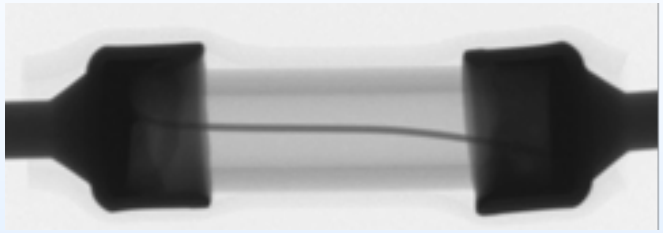
Internal Construction



Circuit Protection Devices

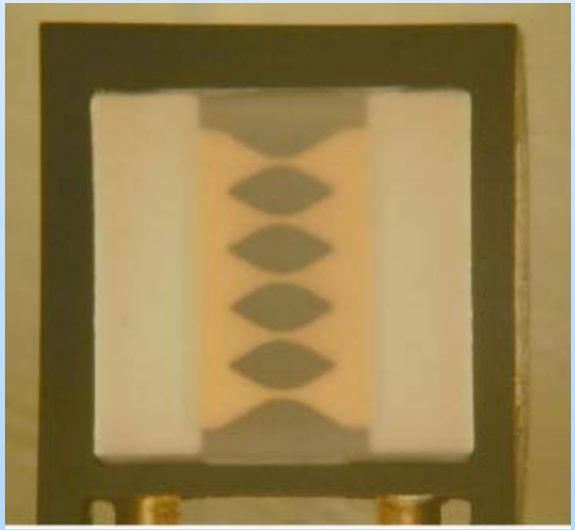
Cartridge Fuse

Internal Construction

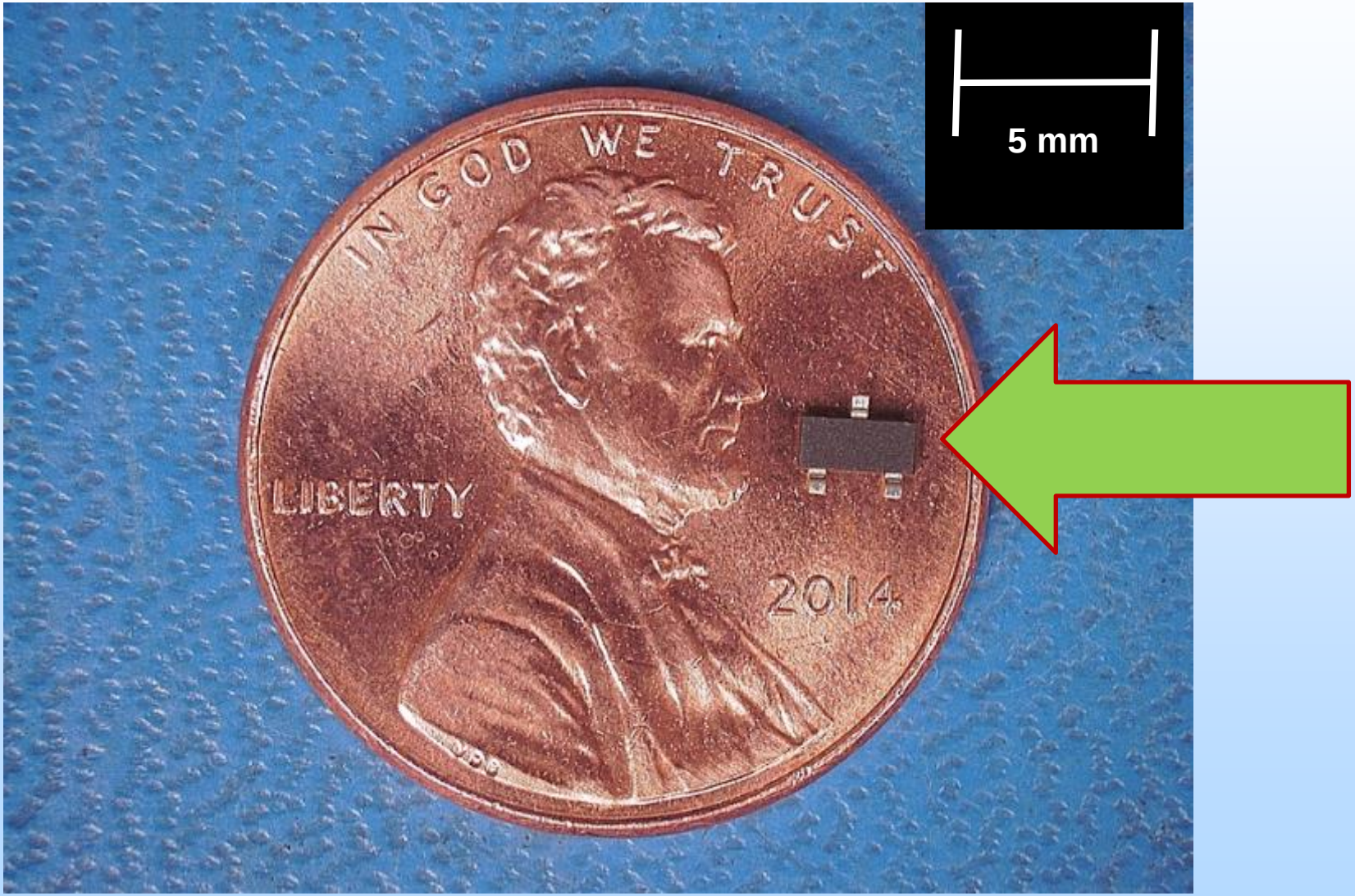


Solid Body Fuse

Internal Construction



And They Can Be Very SMALL



A Little History

- In 1976, MIL-STD-975, the "Standard Parts List for Flight and Mission-Essential Ground Support Equipment", was Released by NASA MSFC
  - Later Re-titled "NASA Standard Electrical, Electronic, And Electromechanical (EEE) Parts List"
- Established a process where parts designated "standard" reflected proven performance, reliability and consistency
  - Standard parts required minimal post procurement testing or analysis compared to Non-standard
  - Most were MIL spec., when MIL spec. was state- of-the-art
- In 1998, 975 was canceled without replacement and the NASA Centers were left to develop parts management procedures
- NASA has a parts policy, NPD 8730.2, which covers EEE parts, mechanical parts and materials at a high level but very limited detailed guidance for EEE parts
- There had been no NASA Standard for EEE Parts Assurance until <u>NOW</u>, NASA-STD-8739.10

Current Policy Documents

- **NPD 8730.2 NASA Parts Policy**
  - **Control Risk and Enhance Reliability, Covers:**
    - **EEE Parts, Electronic Packaging and Interconnect Systems**
    - **Mechanical parts and Manufacturing Materials**
- **NPR 8705.4 Risk Classification for NASA Payloads**
  - **Appendix B: Guidance on acceptable risk levels**
  - **Appendix C: Recommended SMA – Related Requirements**
    - **Critical Single Point Failures**
    - **EEE Part Levels**
    - **Reliability**
- **Center EEE Part Documents**
  - **GSFC: EEE-INST-002 (Also used by LaRC, GRC and JPL)**
  - **MSFC-STD-3012**
  - **ARC: APR 8730.2**
  - **JSC/ISS: SSP 30312**
  - **JPL: IPPR, PETS and PPL"**

https://spinoff.nasa.gov/network.html

NASA TECHNICAL STANDARD

NASA-STD-8739.10

National Aeronautics and Space Administration
Washington, DC 20546-0001

Approved: 2017-06-13

ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL (EEE) PARTS ASSURANCE STANDARD

MEASUREMENT SYSTEM IDENTIFICATION: METRIC/SI (ENGLISH)

MEASUREMENT SYSTEM IDENTIFICATION

MSFC-STD-3012
REVISION A
EFFECTIVE DATE: February 14, 2012

National Aeronautics and Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

ES43

MSFC TECHNICAL STANDARD

ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL (EEE) PARTS MANAGEMENT AND CONTROL REQUIREMENTS FOR MSFC SPACE FLIGHT HARDWARE

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NASA/TP—2003–212242

EEE-INST-002: Instructions for EEE Parts Selection, Screening, Qualification, and Derating

Prepared by:
Dr. Kusum Sahu

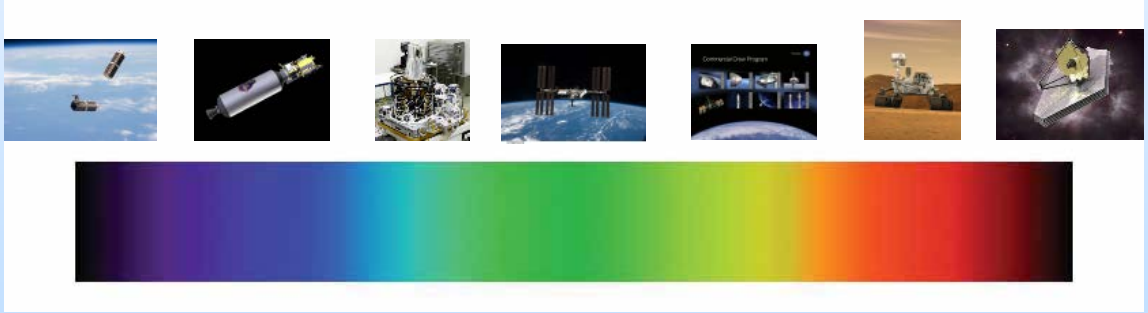
Reviewed by:
Dr. Henning Leidecker

Approved by:
Darryl Lakins

April 2008, Incorporated Addendum 1

Goals for NASA EEE Parts Standard

- **Create Agency-Level Document**
  - **Capture list of issues that must be addressed**
  - **Single document referenced in Agency contracts**
  - **Not overburden “higher risk” projects with excessive requirements**



- **Maintain Center-to-Project relationship**
  - **Center still has ample control**
  - **Project still assumes the risk**

Gap Analysis of Documents

- **Comparison of Agency and Center Documents**
  - **Topics from all source documents used for cross-reference**
  - **No one document covered all topics (portion shown below)**
  - **Agency level documents had most gaps**
  - **Goal was to make Agency level document that covered all topics**

TOPICS	Agency	Agency	JPL	MSFC	GSFC	JSC/ISS	LaRC	ARC	GRC	KSC
	NPD 8732.2C (Revalidated 12/6/13)	NHB 5300 Vol 1F July 1989	See column O	MSFC-STD-3012 Rev A 2012	EEE-INST-002, Apr 2008	SSP 30312 Vol I, Rev K, Sep 1, 2011	EEE-INST-002, Apr 2008	APR 8730.2 June 2009	GLPR 7120.5.30 Nov 3, 2009	KSC-PLN-5406 Oct 22, 2013
Part Types (applicability)			78157 1.0	4	5.1	1.3 & 1.4	5.1	1	5.2	5
Part Grades		1F301.2	78157 2.0	4.1	2.0 & 6.0	3.2.1.2…	2.0 & 6.0	7.1	5.2.2	6
Commercial grade			78157 Table 3	5.5.1	6.7.1	3.2.1.5	6.7.1		5.2.2.a	7
Criticality Categories		Appdx A & 1F301.1	78157 Table 1	S&MA Requirement		3.2.1.2…				6.2.2
COTS assemblies		1F301.4	57732 Appdx A	5.2.2 & 5.9.2	6.2.7	3.16	6.2.7			7
Parts Control Document	5.b.(1) & 5.f.(1)	1F203	78157	5.1		3.1.1		7.1.3	5.2.1	
Parts Control Board		1F201	58792	5.1.2	6.1	5.1	6.1	6.2 & 7.1.2		3.2
Shipping		1F310.1	57252						8.13	
Derating	5.f.(4)	1F306	78157 3.2.2.2 (invokes 34885)	5.4.1 & 5.6.4	6.5	3.8	6.5	7.1.1	5.2.5	12
Failure Analysis			78157 3.5			3.19				
NSPAR		1F201 & 1F301.4c		5.6.3		3.3		7.1.4		7.1

Full Center EEE Parts Gap Analysis

	Agency	JPL	MSFC	GSFC	JSC/ISS	LaRC	ARC	GRC	KSC
	NPD 8730.2C (Revalidated 12/6/13)	See column N	MSFC-STD-3012 Rev A 2012	EEE-INST-002, Apr 2008	SSP 30312 Vol I, Rev K, Sep 1, 2011	EEE-INST-002, Apr 2008	APR 8730.2 June 2009	GLPR 7120.5.30 Nov 3, 2009	KSC-PLN-5406 Oct 22, 2013
Parts Management									
Part Types (applicability)		78157 1.0	4	5.1	1.3 & 1.4	5.1	1	5.2	5
Part Grades		78157 2.0	4.1	2.0 & 6.0	3.2.1.2...	2.0 & 6.0	7.1	5.2.2	6
Commercial grade		78157 Table 3	5.5.1	6.7.1	3.2.1.5	6.7.1		5.2.2.a	7
Criticality Categories		78157 Table 1	S&MA Requirement		3.2.1.2...				6.2.2
COTS assemblies		57732 Appdx A	5.2.2 & 5.9.2	6.2.7	3.16	6.2.7			7
Parts Control Document	5.b.(1) & 5.f.(1)	78157	5.1		3.1.1		7.1.3	5.2.1	
Parts Control Board		58792	5.1.2	6.1	5.1	6.1	6.2 & 7.1.2		3.2
Roles & Responsibilities	5	57732 7.1	Organization Instruction ES43-EE-OI-001				6.2		3
Part Qualification		78157 Table 3	5.2	6.4	3.5	6.4		5.2.3	11
Heritage			5.9.1					2.3a	11
Standard Part		78157 Table 3	5.5.2		3.2.1			5.2.2b	6
Non Standard Part		78157 Table 3	5.5.2		3.3			5.2.2b	7
NPSL (or equivalent)	5.a.(2), 5.f.(2).(b)		5.5.1		6.0 - SSP 30423		7.1	5.2.2.c	16.2, 17
Part selection	5.f.(2)	57732 7.1	5.5.1	6.2	3.2	6.2	7.1.1	5.2, 5.2.2	6.2
SMD, SCD		78157 Table 3	5.5.3	6.2	3.1	6.2			7.4
Waivers	5.f.(2)(a)	78157 1.0	5.5.4					8.9.2	3.2
NSPAR			5.6.3		3.3		7.1.4		7.1
Plastic Encapsulated uCkts		78157 3.2.2.3	5.5.5	6.2.6		6.2.6			E.14
DPA		78157 3.2.2.1	5.3.2.1		3.7				
RGA		78157 Table 3	Notes to Selection Tables V, VI, VII						
PIND		78157 Table 3	5.3.3.1		3.2.1.3				
Xray		78157 Table 3	5.3.3.2						
Non-compliance		78157 1.0	5.5.4					8.9	7.1
PL's - As Designed		57732 7.2	5.6.2		3.15.1			5.7	8
PL's - As Built		57732 7.2	5.6.5		3.15.2		7.1	5.7	8
Screening		78157 Table 3	5.3.3	6.3		6.3	7.2.1	5.2.4	10
Parts Obsolescence	Attachment C	78395 3.1.1	5.7.1	6.7.3	3.2.2	6.7.3		5.4.1	16
GIDEP	Attachment C	3.3.3	5.3.6	6.7.4	3.17	6.7.4	7.1	5.7a, 8.10	15
Suspect parts		57732 5.2	5.8.6						20
Parts Age/Storage Restriction			5.8.3	6.7.2	3.14	6.7.2		5.6	20
Problem parts (High risk)					3.18			5.8	
Review, Audit & Verification of sub-tier parts management		78230	6					2.5	21
Receiving Insp	Attachment C	78230	5.3.4				7.2.3	8.5.2	14.5
ESD		78744	5.8.1	6.7.2	3.12	6.7.2	7.2.3	8.8	20
Envrn Cntrl		38112	5.8.2	6.7.2	3.14	6.7.2		5.5, 8.6.4, 8.7	20
Reuse	5.f.(2)(a)		5.8.7						
Retesting					3.14			8.11	
Shipping		57252						8.13	
Derating	5.f.(4)	78157 3.2.2.2 (invokes 34885)	5.4.1 & 5.6.4	6.5	3.8	6.5	7.1.1	5.2.5	12
Failure Analysis		78157 3.5			3.19				
GSE / Interfaces		several	5.10		3.2.1.6				6.2.1
Flow-down req's	5.f.(3) & Attachment C	58032 5.14.3.3	5.1.2		1.3, 3.1			P.2a, 2.2	1
Handling/Storing Moisture Sensitive Plastic surface Mount Devices		57732 5.1							
Radiation									
General Req's		78157 3.3	5.4.3	6.0 & 6.8.1	3.9	6.0 & 6.8.1	7.1	5.2.6, 3.6	9
RLAT			5.4.3						
TID			5.4.3		3.9			5.2.6.1	
ELDRS			5.4.3					3.6.b	
DD			5.4.3					5.2.6.3	
SEE			5.4.3		3.9			5.2.6.2	
SEU									
SET									
SEL									
SEGR									
SEB									
Hazard Avoidance / Prohibited Materials									
Prohibited Materials		78157 3.4	5.4.4		3.2			5.9	19
Pure tin	5.f.(5) & Attachment B	78157 3.4.1	5.4.4.1		3.2			5.9	19
oxygen enriched envirnmnt			5.4.4.2						
outgassing reqs			5.4.4.3						
thermal bake / stress corr			5.4.4.4						
cuprous oxide			5.4.5						
Parts Procurement / Counterfiet Avoidance									
Mnfctr or Auth. Distrbtrs		57732 4.1 (invokes 78395)	5.3.1	6.6.4	3.10.2	6.6.4	7.2.1	5.4a	7.3, 14.1
Audits	5.c.(1) & Attachment C	78322	5.3.1.1	6.6.2	3.6	6.6.2			
Traceability	Attachment C	57732 4.2	5.5.7		3.10.2		7.2.2	5.7d, 8.4	13
CoC	Attachment C	57732 4.2		6.6.1		6.6.1		5.4b	13.4
Test data	Attachment C	57732 4.2.2			3.7.3				
Cust Src Insp	Attachment C	78157 Table 3		6.6.3	3.10.3	6.6.3			
Test Lab assessment		78322, 34880		6.6.5	3.7.2	6.6.5			
Counterfiet Avoidance	5.c.(5), 5.f.(6) & Attachment C	57732 4.1	5.7.2				7.4	5.4a	14

Details

- **Applicability**
  - Flight hardware - Launch vehicles - Critical ground support equipment (GSE) - Critical ground test systems
  - Category 1 and Category 2 projects as defined by NPR 7120.5, NASA Space Flight Program and Project Management Requirements
  - Class A, B, C or D payloads as defined by NPR 8705.4, Risk Classification for NASA Payloads, Appendix A.
- **Non – Applicability**
  - Institutional projects as defined by NPR 7120.7, NASA Information Technology and Institutional Infrastructure Program and Project Requirements
  - Research and Technology Development Programs and Projects as defined by NPR 7120.8, NASA Research and Technology Program and Project Management Requirements
- **Tailoring**
  - Tailoring of the requirements contained in this Standard for application to a specific program or project per Center requirements, risk classification or acceptable risk posture shall be formally documented in the Program and Project EEE Parts Management and Control Plan (EPMCP), or equivalent, and approved by the Parts, Materials, and Processes Control Board (PMPCB), or equivalent, and the Technical Authority.

More Details…

- **Every EEE part intended for use in space flight and critical ground support equipment shall be reviewed and approved for compatibility with the intended environment and mission life, as applicable.**
- **Parts shall be selected so that flight hardware meets all performance and reliability requirements in the worst-case predicted mission environment**

EEE Part Grade Description

	SUMMARY	LEVEL OF IN-PROCESS CONTROLS AND SCREENING	COST/ PART	POTENTIAL UPSCREEN COST	TYPICAL USE
1	Space quality class qualified parts or equivalent.	Highest	Highest	Low	Space flight.
2	Full Military quality class qualified parts or equivalent.	High	High	Medium	Space flight or critical ground support equipment.
3	Low Military quality class parts and Vendor Hi-Rel or equivalent. Screened automotive grade EEE parts.	Medium	Moderate	High	Space flight experiments, cube-sats noncritical space flight, critical ground support equipment, test demonstrations and ground support systems.
4	“Commercial" quality class parts. Qualification data at manufacturer’s discretion. No government process monitors incorporated during manufacturing.	Variable	Lowest	Highest	Cube-sats, noncritical space flight, noncritical ground support equipment, ground support systems, test demonstrations and prototypes. Limited critical GSE.

Content of NASA-STD-8739.10

1. Scope
2. Applicable Documents
3. Acronyms and Definitions
4. EEE Parts Classification
5. EEE Parts Selection Requirements
6. EEE Parts Assurance and Control Requirements
    1. Scope
    2. Qualification – Environmental and life testing (often accelerated)
    3. Screening – 100% test for burn-in and parametrics
    4. Government Industry Data Exchange Program (GIDEP) Review
    5. Receiving Inspection
    6. Environmental Control and Storage Requirements
    7. Electrostatic Discharge (ESD) Control
    8. Re-use of EEE Parts
7. EEE Parts Procurement, Obsolescence and Counterfeit Avoidance
8. EEE Parts Documentation and Organization

Lists of Appendices and Tables

Documentation

- **Program / Project EEE Parts Management and Control Plan (EPMCP)**
  - **Plan can be stand-alone documents of part of Project Product Assurance Plan**
  - **Specific Issue Plans may be contained in EPMCP or stand-alone doc's**
- **Parts Lists**
  - **(EPARTS recommended)**
  - **As Designed Parts List**
  - **Approval Record**
  - **As Built Parts List**
- **Analyses**
  - **Derating Analysis**
  - **Parts Obsolescence**

Documentation (continued)

- **Specific Issue Plans**
  - **Radiation Hardness Assurance Plan**
  - **Counterfeit Control Plan**
  - **Restricted Materials Plan**
    - **NASA-STD-6016 - Standard Materials and Processes Requirements for Spacecraft**
  - **Red Plague Control Plan**
    - **IPC J-STD-001 ES - Space Applications Electronic Hardware Addendum to IPC J-STD-001E Requirements for Soldered Electrical and Electronic Assemblies**
  - **Prohibited Materials:** **Sn, Hg, Zn, Cd …**

Current Status of NASA-STD-8739.10

- **Workgroup participation from NASA Centers handling space electronics**
  - **LaRC, GSFC, MSFC, KSC, JSC, ARC, GRC & JPL**
- **Stakeholder Review**
  - **238 comments submitted, all resolved**
  - **Approximately 1 year duration**
  - **11 Center/Organizations [#comments]**
    - **ARC [1], GRC [18], GSFC [33], HQ (OSMA) [51], JPL [20], JSC [72], KSC [3], LaRC [9], MSFC [1], NSC [25], SSC [1]**
- **Document has been approved by the Office of Safety and Mission Assurance (OSMA) at NASA HQ**
- **Currently waiting on export control (ITAR) and legal reviews**
- **Currently available to NASA only, requires sign in through IdMax:**

Electronic Parts Application Reporting & Tracking System (EPARTS)

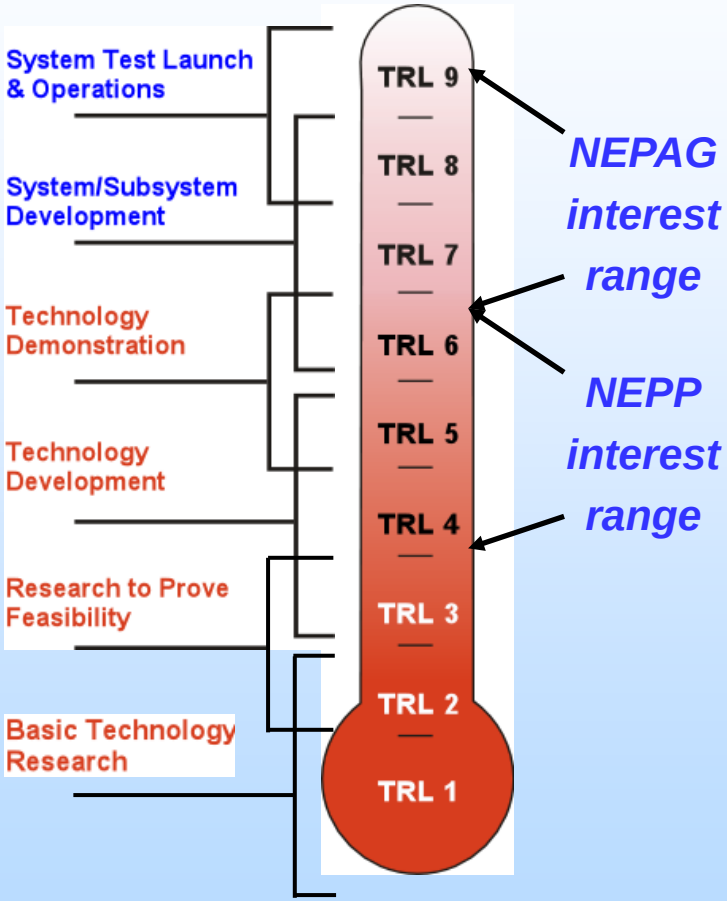
- **Leveraged off JPL's "Part Acquisition & Review System" (PARS)**
  - **Primary Purpose: Track Parts status from initial upload (Parts Lists) through Review, Approval and Procurement**
  - **Repository of all data for Parts, Reviews, Testing, Up-screening, Waivers…**
- **Current Status**
  - **Operational with participating Centers:**
    - **MSFC, LaRC, ARC, KSC, and GRC.**
    - **JPL and JSC not currently using the database but participating in EPARTS working group.**
  - **Behind NASA firewall and accessible by all Centers through Launchpad credential.**

NEPP and NEPAG

- **Chartered in the 1980's to ensure electronic commodities expertise supported the Agency.**
  - **The NASA Electronic Parts Assurance Group (NEPAG) was created in 2000, as a sub-element of NEPP for**
    - **Information sharing between NASA Centers and other agencies, and**
    - **Sufficient infrastructure to support Agency needs and leadership in EEE Parts Assurance**
- **NEPP evaluates new EEE parts technologies and develops insertion, test, screening, and qualification guidance.**
- **NEPAG supports audits, specification and standard reviews, failure investigations etc. AND**
- **Maintains the NASA Parts Selection List (NPSL)**

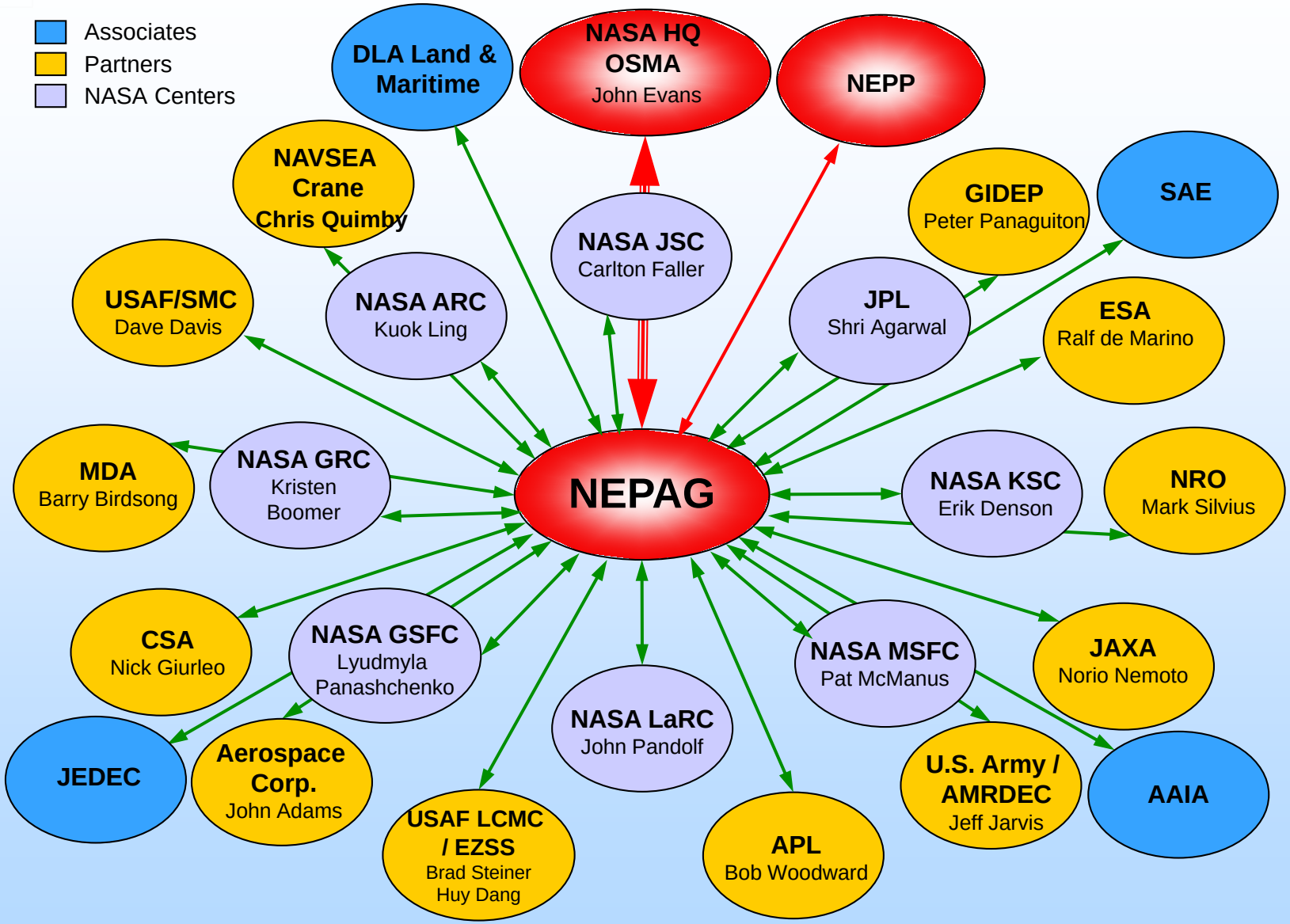
Insertion of New Technologies – NEPP/NEPAG Focus

- **NASA mission timeframes rarely allow for a technology development path**
- **For a 2017 launch, technology freeze dates are likely 2014 or earlier**
  - ***There may be time to qualify (test) a device, but there may not be time to develop/validate a new technology solution!***
- **Technology development and evaluation programs need to be in place prior to mission design**
  - ***Strategic planning for/by NEPP on technologies is critical***



NASA Technology Readiness Levels (TRLs)

NEPAG "Extended Family"



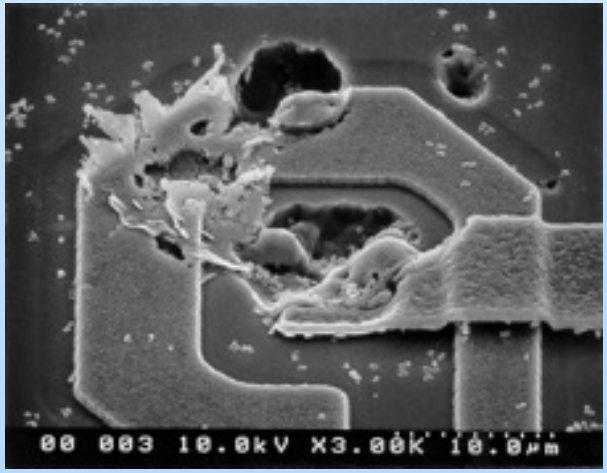
Program Highlights

- ***NEPAG has celebrated 17 years of stimulating, weekly discussions and knowledge interchange that is/has been Educational, Influential, Collaborative, and Current***
  - ***New multi-agency Working Group established for coordinated disposition of proposed changes to specifications and standards***
- ***NEPAG acts as the NASA Custodian in the Military Standardization Program***
- **Working with Aerospace Corporation to develop an agreement to share support of MIL QPL/QML audits led by the Defense Logistics Agency Land and Maritime**
- **NEPP evaluates new parts and packaging technologies and publishes guidance for qualification for space use**
- **NEPP performs Total Ionizing Dose (TID) and Single Event Effects (SEE) testing to characterize the sensitivity (or hardness) of new and emerging technologies known as Radiation Hardness Assurance (RHA)**

Importance of ESD

- **Potentially affects everything, even mechanical parts, and there are major differences among the multiple ESD specs in use.**
- **There are ongoing efforts by various standards groups toward harmonizing the different standards.**
- **1686 is the original MIL document for ESD testing and control, and it could be built up into a major ESD spec. However, Office of Management and Budget (OMB) Circular A-119 favors Industry Standards over government ones.**

MIL-STD-750, MIL-STD-883, MIL-PRF-38535 and probably other MIL documents, call out MIL-STD-1686 Requirements



NASA Concern - ESD

Electro Static Discharge (ESD)

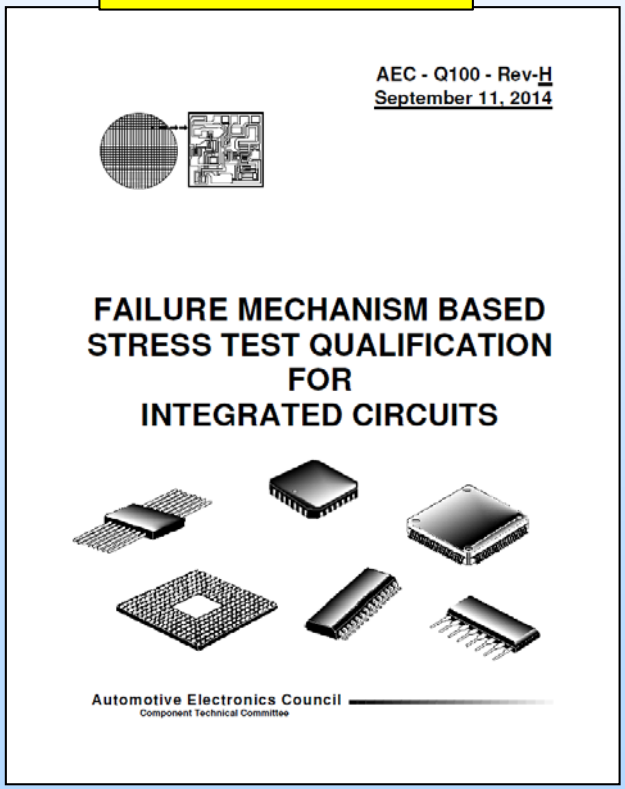
- **MIL-STD-883, Test Method 3015**
  - **Too old, long test times**
  - **Needs to be revisited for new technology**
    - **Smaller feature sizes, lots of contacts/pins, advanced packaging (2.5/3D)**
  - **883 vs JEDEC (3 zaps/pin vs 1 zap/pin, for HBM test)**
  - **Equipment used to assemble /process parts/wafers need closer look – special talk at Space subcommittee meeting**
  - **Generic issue; applies to all parts military/space (and COTS)**
- **MIL-PRF-38535, Microcircuits:**
  - **Clarify requirements**
    - **No specific ESD requirements for wafer foundries**
- **NASA EEE Parts Bulletin**
  - **Published a special edition on ESD, 2nd part published soon**
- **NASA ESD Surveys**
  - **Conducted to bring awareness**

AEC "Q" Specs

Qualification Requirements for EEE Parts FAMILIES Intended for use by Automotive Market

http://www.aecouncil.com/AECDocuments.html

AEC Q-100 Microcircuits


AEC - Q100 - Rev-H
September 11, 2014

FAILURE MECHANISM BASED
STRESS TEST QUALIFICATION
FOR
INTEGRATED CIRCUITS

Automotive Electronics Council
Component Technical Committee

AEC Q-101 Discrete Semiconductors


AEC - Q101 - Rev – D1
September 6, 2013

FAILURE MECHANISM BASED
STRESS TEST QUALIFICATION
FOR
DISCRETE SEMICONDUCTORS
IN AUTOMOTIVE APPLICATIONS

Automotive Electronics Council
Component Technical Committee

AEC Q-200 Passives


AEC-Q200 REV D
June 1, 2010

STRESS TEST QUALIFICATION
FOR
PASSIVE COMPONENTS

Automotive Electronics Council
Component Technical Committee

Alternate Grade Electronics: Automotive

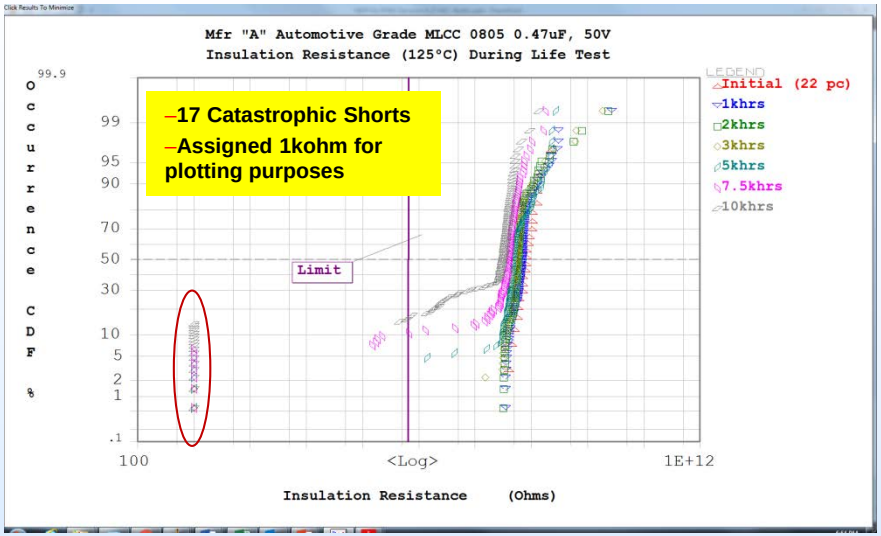
- **NEPP has three goals for automotive electronics efforts**
  - **Determine exactly what :"automotive grade" does or does not entail.**
    - **Includes understanding:**
      - **Automotive Electronics Council (AEC) documents, and,**
      - **Manufacturer Production Part Approval Process (PPAP).**
  - **Perform "snapshot" screening and testing on representative automotive grade electronics.**
  - **Explore adaption of resilient automotive electronics system concepts for use in space applications.**

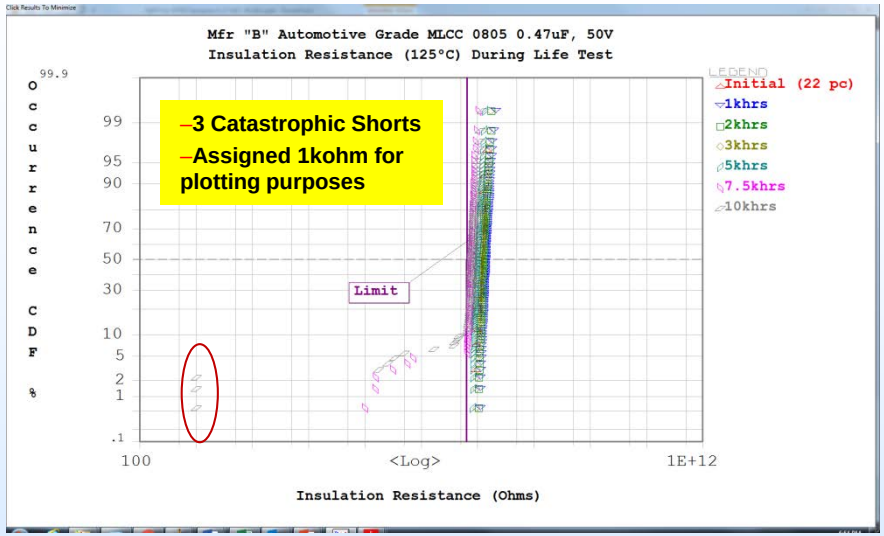
NEPP Evaluation of Automotive Grade EEE Parts

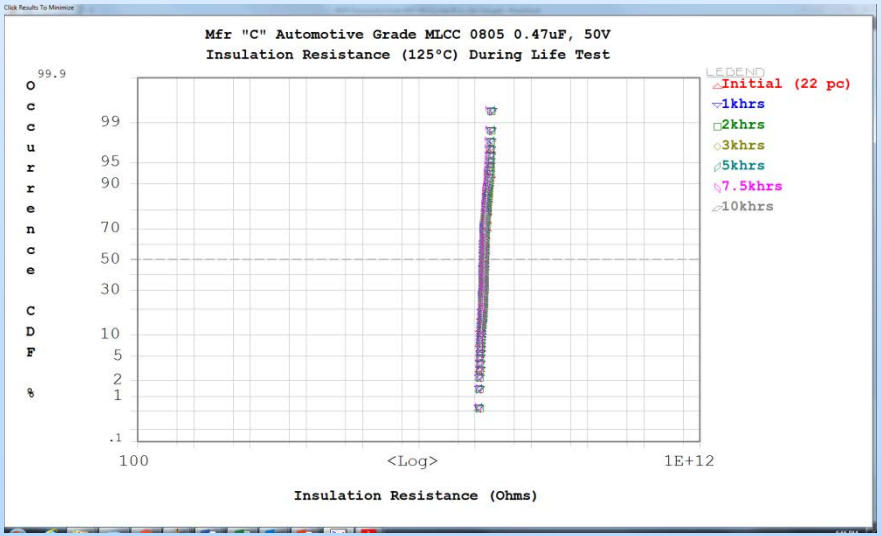
20-Mar-17

Manufacturer	Lot Code	Description	Quantity on Test	Life Testing Status	Comments
A	1302	Ceramic Chip Capacitor, 0805, 0.47uF, 50V	120	10khrs	120 pcs on test. 17 catastophic life test failures with first occurring ~3.1khrs
B	1304		120	10khrs	120 pcs on test. IR degradation noticed @7.5khrs; 3 catastrophic failures beyond 8khrs of test
C	1131		120	10khrs	120 pcs on test. No Catastrophic Life Test Failures
D	201028	Ceramic Chip Capacitor, 0402, 0.01uF, 16V	78	8k Hrs	few devices exhibit reduced IR (non-catastrophic)
E	TBD		80	8k Hrs	few devices exhibit reduced IR (non-catastrophic)
F	1247		79	8k Hrs	Stable IR Note: Precious Metal Electrode
AA	N/A	Tantalum Chip Capacitor, 22uF, 35V	80	2k Hrs	No Catastrophic Failures; ~10% show hot DCL above spec limit
AA	1301	Tantalum Chip Capacitor, 220uF, 10V	80	2k Hrs	No Catastrophic Failures;
G	TBD	Microcircuit, Transceiver	50	Not yet started	sent boards for fabrication
H	1152	Microcircuit, Comparator	90	2k hrs	Two setups, 45 units each. No failures.
I	1341	Microcircuit, comparator	50	Not yet started	Test Program in Development
J	unknown	Dual small signal NPN Bipolar transistor (similar to 2N2919 and 2N2920 MIL-PRF-19500/355)	20	>5k Hrs	No failures to Date Second batch of 20 devices in process to start life
K	1339	Switching diode (similar to 1N4148, MIL-PRF-19500/116)	20	100 hrs life test	No Failures to Date Parametric Degradation Observed beginning TA ~ 40°C behaves like short circuit >105°C
*L	unknown	Transient Voltage Suppressor, 36V minimum breakdown voltage, 400 watt peak pulse power	20	Not yet started	Test plan and test boards being validated Testing to commence 3rd or 4th QFY17

AEC-Q200: 0805 Ceramic Chip Capacitors, Insulation Resistance at 125^{0}C During Life Test







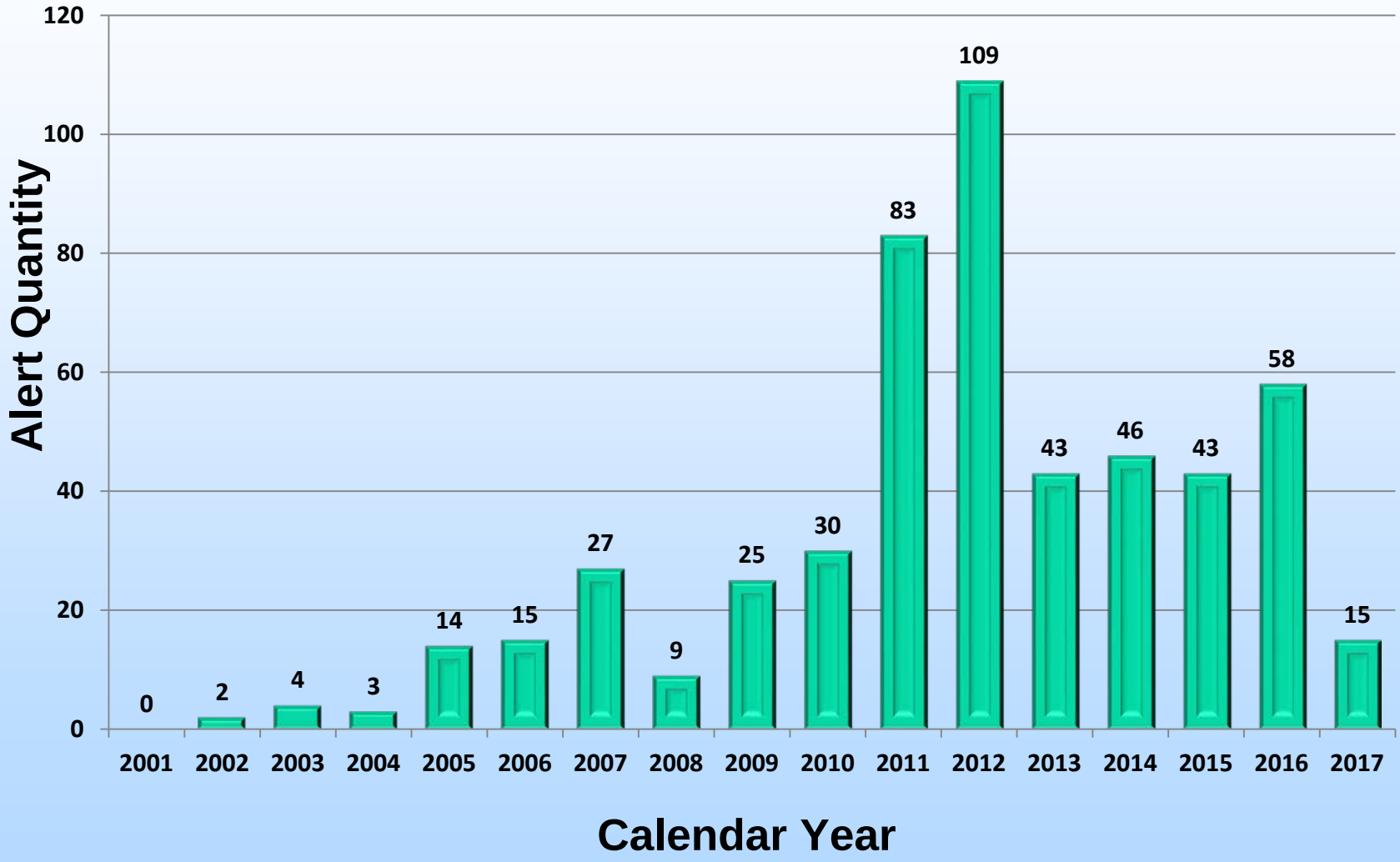
Reverse-bias Tantalum Chip Capacitors

- Capacitors in International Space Station experiment pallets known as Express Logistics Carriers (ELCs) were found installed backwards
- They have so far functioned satisfactorily for more than 6 years on orbit
- The risk of failure needs to be understood to avoid further extravehicular workarounds (one avionics pallet out of four has been replaced out of an abundance of caution).
- Why are the capacitors not failing and what performance envelope must they occupy to avoid failure for as long as possible?
- Experiments in progress to look at effects of voltage, temperature and humidity

Multi-layer Ceramic Capacitors (MLCCs)

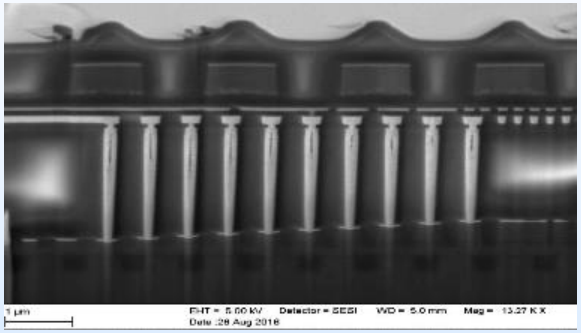
- **NASA has recently experienced 2 on-orbit MLCC anomalies on one project and a failure on a different project**
  - **Characteristics duplicated on spare hardware**
- **Both came from same 2010 lot**
- **Investigation has found previous indications of similar anomalies going back to at least 2004 and a discovery of another NASA instrument failure in 2014 traceable to the same problem (2005 lot)**
- **Anomalies are a gradual, yet significant increase in leakage currents and are associated with internal delaminations (delams) present in the lots and cross dielectric cracks in the anomalous parts**
- **Handling and soldering stresses may be causing a sub-population to develop new or exacerbate pre-existing delams, cracks or other weak features in the parts. They passed all MIL specification tests**
  - **Exploratory experiments are ongoing**
- **Indications are this problem was recognized years ago but not communicated in a way NASA could hear**

Quantity of Counterfeit EEE Parts Alerts per Year

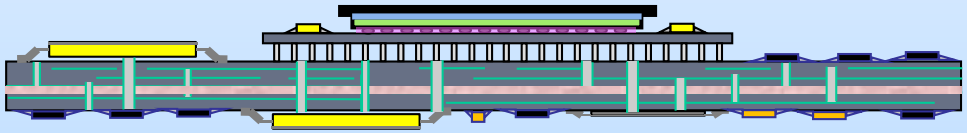


Some Upcoming Challenges

- **Complexity issues for inspection, screening, device preparation, and test**
  - **2.5/3D Packages/ICs**
  - **Package on Package (PoP) Commercial Devices**
  - **An FPGA combined with an SOC (MPSOC+ from Xilinx)**
  - **Cu Wirebonds**



Surface Mount with Embedded C or R Layer



- **Assurance**
  - **Automotive and catalog commercial EEE parts?**
  - **Increasing risk with a worldwide supplier base**
    - **Standardization Source Consolidation.** ***What if the only source left is in an inhospitable or unauditable part of the world?***

Summary and Comments

- **Assuring the Performance and Reliability of EEE Parts is a Multi-disciplinary Endeavor**
- **The EEE Parts Specialist Needs to Know Key Properties, Features, Behaviors and Methods for:**
  - **Materials – Metals, Organics, Ceramics, Alloys, Composites etc.**
  - **Processes – Soldering, Welding, Bonding, Casting, Crimping, Encapsulating, Etching, Plating etc.**
  - **Environmental Testing – Temperature, Humidity, Shock, Vibration, Radiation Effects, Hermeticity, etc.**
  - **Electrical Testing – Dynamic, Steady-state, Accelerated, Parametric, Automated, etc.**
  - **Analysis – Non-destructive, Destructive, X-ray, Microscopy, (visual, ultrasonic, electronic, x-ray fluorescence), etc.**
- **And of Course, the EEE Parts Specialist Needs a Basic Understanding of Circuit Functions and Applications**

Questions?

https://nepp.nasa.gov